COPEPODA AND CLADOCERA POPULATIONS
OF RED ROCK RESERVOIR, IOWA
FROM APRIL TO NOVEMBER, 1970

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by

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INTRODUCTION

Within the last two decades the U.S. Army Corps of Engineers has created some vast changes in the landscape of midwest America. These man-made changes have not only changed the landscape, but have had a definite effect on the ecosystems of several streams and major river systems. These changes have included: a series of dams and reservoirs on the Missouri River, several reservoirs on streams in Eastern Kansas, and within the State of Iowa, three reservoirs (Coralville, Red Rock, and Rathbun) have been completed and the Saylorville Reservoir is currently under construction. The main functions of these structures as stated by the U.S. Army Corps of Engineers are for flood control and the maintenance of downstream flow during periods of low water.

Each lake or reservoir is an individual problem with its own peculiar chemical, physical, and planktonic characteristics (Schmidt, 1968). Reservoirs should be studied as a complete system; delineating physical and chemical characteristics as they influence biological populations.

By selecting stations within a reservoir along the line of water movement it should be possible to show population development. Changes in numbers of individuals of various species should indicate changes in population density. Analysis of the reservoir water level and outlet discharge rate should provide the information to determine flushing rate. Chemical analysis of the water should determine whether nutrient renewal was taking place. Perhaps when this data can be assembled one could begin to understand what factors have a controlling effect on the occurrence of animal populations and their density fluctuations.

The physical and chemical characteristics of these man-made lakes are different from those in natural lakes. Waters in Coralville Reservoir were characterized by high turbidity and alkaline pH. Thermal stratification occurred rarely and any slight stratification was soon modified by wind action (Schmidt, 1968). Lewis and Clark Lake and Francis Case Lake, South Dakota, were much the same. During the summer months the phosphorus concentrations were lower in Francis Case, the upstream reservoir (Cowell, 1970).

Lake West Okoboji, a natural Iowa lake has been extensively studied (Birge and Juday, 1920; Stromsten, 1926; Jahn and Taylor, 1940; Bardach, 1954). The presence of a distinct thermocline depends upon spring weather conditions (Stromsten, 1926) and depth (Birge and Juday, 1920). In Miller's Bay, Lake West Okoboji, turbidity and transparency values were related to plankton blooms (Cooke, 1966).

In artificial lakes in southern Iowa during the summer, fourteen of 36 did not stratify or had temporary stratification (Moen, 1956). East Lake Okoboji because of its shallow water did not stratify thermally due to wind conditions. It had an alkaline pH, very low amounts of soluble phosphate and nitrate (Volker, 1962). Clear Lake did not thermally stratify because of its shallow depth. Temperatures varied only a few degrees between the surface and the bottom. Secchi disc readings were correlated to phytoplankton blooms and suspended soil particles (Pearcy, 1953).

Iowa rivers differ from the lakes in their water chemistry. A fall study of the Des Moines River was characterized by higher pH, nitrate, and phosphate, than were found in Iowa natural and artificial lakes (Drum, 1963).

A three year pre-impoundment study of the Des Moines River showed that nitrate values were highest during winter, spring, and periods of high stream flow. Orthophosphate values decreased during winter and spring (Baumann and Kelman, 1970).

In a pre-impoundment study of the Cottonwood River, Kansas, nitrate and phosphate levels tended to decrease throughout the summer from a high during June, when discharge was greatest, to a low in August when discharge was less (Scobee and Prophet, 1967). An earlier impoundment on same river system followed a similar pattern (Prophet, 1966).

The composition and abundance of Cladocera and Copepoda populations may be used as indicators of conditions within a reservoir or lake. These populations may be influenced by primary production, reservoir retention time, and climatic factors such as temperature.

Zooplankton populations studied in Francis Case Lake and Lewis and Clark Lake (Tash, et al., 1966; Cowell, 1970) showed distinct population peaks in the spring and fall with a summer minima. Schmidt (1970) studied abundance of zooplankton in Coralville Reservoir and determined that cladocerans were abundant during high water periods. The zooplankton species diversity in three Kansas Reservoirs showed little similarity with regard to dominant forms (Prather and Prophet, 1969).

Of the studies done within the State of Iowa on zooplankton most have concerned the natural lakes found in the northern part of the state (Stromsten, 1920a, b; McDonald, 1939a, b; Kutkukh, 1958). The occurrence and abundance of a particular species was related to the time of the year (Bülkley and Scheider, 1970).

The flow of water through a lake (flushing rate) can be a limiting factor on the productivity of a lake. In Marion Lake, British Columbia, Dickman (1969) showed that high flushing rate contributed to low primary productivity by removing the organisms via the outlet or "cropping" them.

Cowell (1967) reviewed the literature concerning the influence of the water exchange rate (flushing time) and discharge of zooplankton from upstream basins in lower basins. It was found that the water exchange rate must be greater than 18 days for significant development of zooplankton within a lake. There was a general downstream increase of zooplankton in lake basins. Plankton communities in downstream lakes seemed to be controlled by discharges from upper lakes. The latter statement was substantiated when Cowell (1967) showed that standing crops in Lewis and Clark Lake were determined by discharges of zooplankton from Lake Francis Case. However, the outlets of lakes may be avoided by some zooplankton (Hutchinson, 1967).

Little has been done on the zooplankton of the Des Moines River. The microflora of the Des Moines River were studied by Starrett and Patrick (1952).

The zooplankton of Red Rock Reservoir is currently being studied by the Biological Division of the Iowa Conservation Department to examine volumes as related to the reservoir fisheries. The data is currently being analyzed (Mayhew, 1971).

It is the intent of this current study to explain: the species composition, the relative abundance, and some reasons for fluctuations in population abundance of the Copepoda and Cladocera of Red Rock Reservoir. The effects of nutrient renewal, conservation pool water level, and the average weekly discharge rate on these zooplankton populations will be determined.

MATERIALS AND METHODS

Red Rock Reservoir is located in south central Iowa, 8 km north of Knoxville. Red Rock Reservoir is a U.S. Army Corps of Engineers flood control project on the Des Moines River. Under normal river conditions the conservation pool extends 18.2 km upstream from the dam. The surface of the conservation pool is 221.0 m above mean sea level. At conservation level the reservoir has a surface area of 3,623 ha and an average depth of 3.1 m. During flood control operations the surface area may increase to 26,500 ha with an average depth of 8.1 meters and a length of 53.9 kilometers.

Three transects were selected to divide the conservation pool into approximately three equal parts. Transect one was located through the deep water area near the dam. Transect two was located near the middle of the reservoir. Transect three was located in the upper end of the reservoir to represent the effects of the entering river. Ten sampling sites were positioned on these transects (Figure 1). Stations one and two were located on either side of the dam outlet. Stations three, six, and eight were in the old river channel. Station four was positioned in White-Breast Bay on the old creek channel.

From April 17 to November 6, 1970, volumetric samples of free swimming zooplankton were collected at weekly intervals between 9:00 and 12:00 A.M. Organisms were

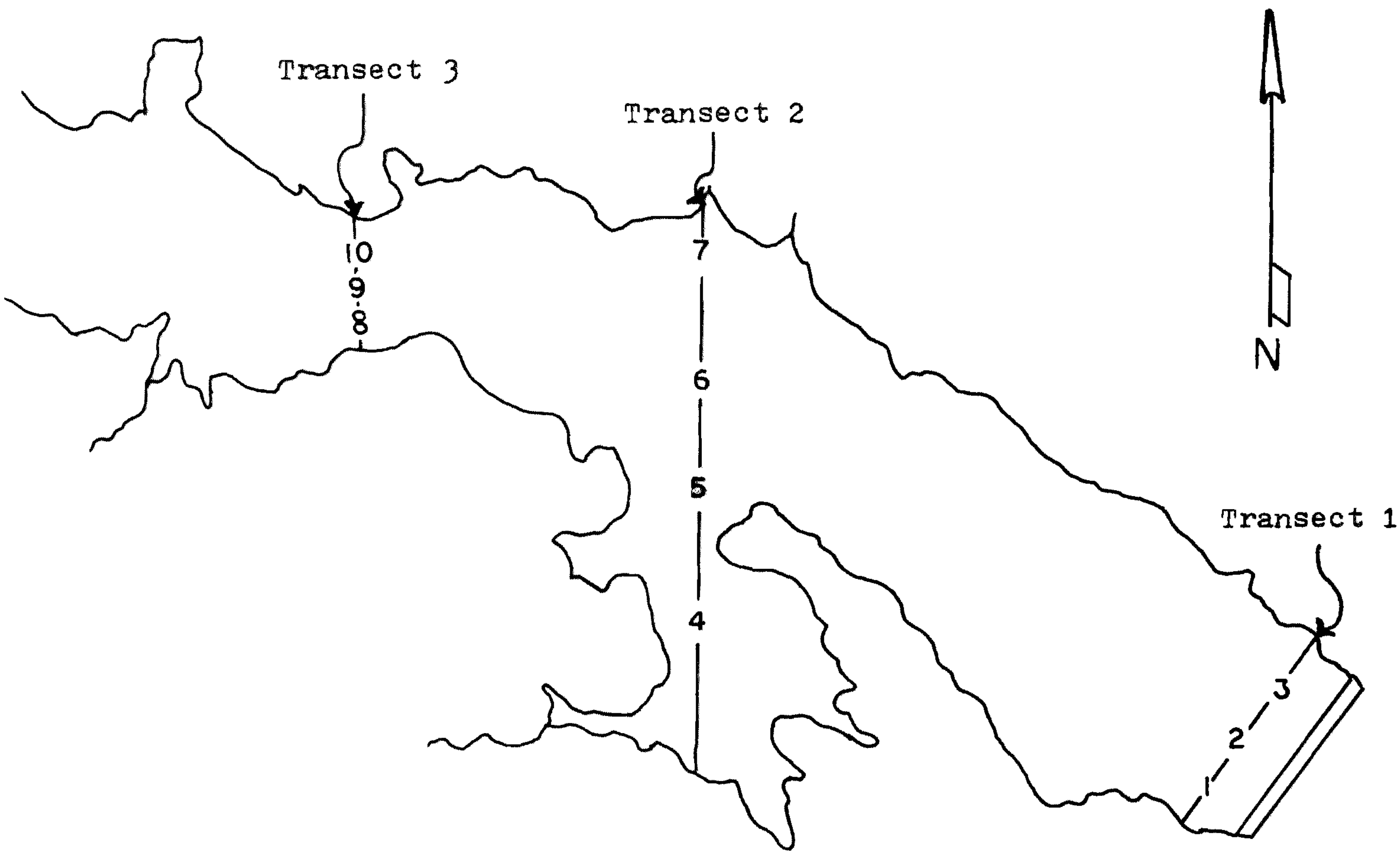

Figure 1. A map showing the location of the stations and transects on Red Rock Reservoir.

collected with a three liter Kemmerer water bottle. The valves were released as soon as the sampling depth was reached. Six liters were collected from each depth. The sample depths varied from the surface (56 cm) to 6 meters depending upon the individual station. Stations located near the dam and within the old river channel varied from 5 to 6 meters in depth. The other stations varied from 1 to 2 meters in depth except station four which was 5 meters. The Kemmerer samples from each depth were concentrated by emptying the contents into a conical No. 20 mesh plankton net with attached vial. The net was dipped partially into the water after each sample to wash the organisms from the net into the vial. Samples were preserved in ten per cent formalin and returned to the laboratory for examination.

Physical measurements taken at each station included the temperature at each sampling depth using an electrical resistance thermometer and light penetration using a 20 cm Secchi disc.

The Iowa State Hygenic Laboratory, Des Moines, Iowa, analyzed the water samples using the phenoldisulfonic acid method for nitrate and the aminonaphtholsulfonic acid method for the orthophosphate (American Public Health, 1965). The pH was determined using a Beckman Expandomatic Laboratory pH meter Model No. 76A. Turbidity was determined using the Hellige Turbidimeter. The water samples for chemical analysis were taken biweekly during the morning at the surface (56 cm) and 4.3 meters by the Iowa State Conservation Commission personnel. Water samples were obtained at five stations: one downstream from the dam outlet, one upstream, and three within the conservation pool. Two of the water sampling stations coincided with stations one and eight. The third water sampling station was located downstream from station six.

On July 17, 1970, samples were taken at station three using both the Kemmerer and Van Dorn samplers. The purpose for taking these samples was to determine the avoidance reaction noted by Parr (1967). The avoidance reaction is apparently caused by the turbulence of the sampler as it passes through the water and due to changes in light intensity caused inside the brass sampler. The Van Dorn sampler causes less turbulence as it is lowered and less change in light intensity with its clear plastic tube. Ten samples were taken with each device at a depth of three meters. Each sample was concentrated with the plankton net and collected in the attached vial. The samples were preserved in ten per cent formalin and returned to the laboratory for examination. The means and standard errors for the numbers of each species collected by each method and the results of the Student's t-test (Sokal and Rohlf, 1969) are shown in Table 1. Significant differences were not found, except for Diaphanosoma sp. There was no significant difference between the total numbers collected.

Table 1. Means, standard errors, and t-values for the comparison of the Kemmerer and Van Dorn samplers. Samples were taken at station 3 at 3 m on July 17, 1970. (*significant, **highly significant). N = 10.

Species	Kemmerer Mean ± S.E.	Van Dorn Mean ± S.E.	t-Test
Cyclops sp.	62.6 ± 7.51	70.9 ± 7.04	-0.80
Diaptomus sp.	35.9 ± 6.86	28.3 ± 5.28	0.88
Daphnia sp.	2.0 ± 0.49	1.0 ± 0.33	1.68
B. longirostris	37.8 ± 3.64	45.8 ± 11.9	-0.67
M. micrura	13.8 ± 2.90	15.0 ± 3.53	-0.26
Diaphanosoma sp.	1.5 ± 0.45	3.7 ± 0.47	-3.36**
Total number of all animals	153.7 ±19.2	164.4 ± 25.6	-0.34

In the laboratory the contents of each plankton sample were placed in a gridded plastic petri dish for enumeration and genus identification using a dissecting microscope. Species determinations were made on representative numbers of each genus.

The Copepoda were identified to species using: Czaika and Robertson (1968), Pennak (1953), Pennak (1963), Wilson (1959) and Yeatman (1959). The Cladocera were identified using: Brooks (1959) and Pennak (1953). *Daphnia* identifications were based on Brooks (1957). *Moina* were determined using Goulden (1968).

Several representative animals from each species were stained and mounted in Turtox CMC-10 and CMS mounting media and sealed. These provided a reference collection.

Appropriate calculations were made to determine the average number of each individual species per liter per meter at depth at each station and per transect. The statistical analysis of the sample data was done using the multiple regression program of the Honeywell Model 1200 Computer at the Dial Computer Center at Drake University, Des Moines, Iowa.

RESULTS

Physical and chemical data.

Water temperatures recorded at each station are shown in Appendix A. Water temperature showed a gradual increase until July 2 when the maximum temperature (29°C) was reached at the surface at station 8. Then there was a gradual decrease until the lowest temperature (6.5°C) was observed on November 6, also at station 8.

The maximum temperature difference within the reservoir was five and one-half degrees between the surface and the bottom, this occurred at station eight on July 10. The majority of the time the difference in water temperatures ranged from zero to two degrees from the surface to the bottom, apparently due to wind action which caused mixing to occur.

Secchi disc readings (Appendix B) ranged from 5 to 100 cm. The maximum occurred during the first week in July on transect one. The lowest readings occurred along the stations of transect three and at station four following a heavy rainstorm.

A general trend noted during this study was that wind had a direct effect on the water transparency. The shallow stations were directly affected by wind and wave action which caused a decrease in the Secchi disc readings. The longest dimension of the reservoir is from southeast to northwest. Prevailing winds during the spring and fall occurring from a northerly direction had a direct effect on the water transparency. During the summer months the prevailing winds were from the south and had an equally direct effect.

The pH, turbidity, nitrate, and phosphate values are shown in Appendix C. The pH values ranged from 7.1 to 8.2. During the influx of runoff into the reservoir the pH of the water was lowered. Turbidity values varied from 30 to 1,000 mg/l. The highest turbidity value recorded was found during an influx of runoff from White-Breast Creek into White-Breast Bay (sta. 4). Nitrate nitrogen values ranged from 0.2 to 5.6 mg/l and phosphate values from 0.1 to 0.9 mg/l.

The daily discharge rate and water level of the conservation pool were obtained from the U.S. Army Corps of Engineers. Mean weekly discharge rate and water level values were obtained by summing the daily values for one week (Saturday to Friday) and dividing by the number of days included (Appendix D).

The conservation pool level was 221.0 meters above mean sea level. The high water levels recorded were: May 20, 224.1; August 9, 222.8; September 18, 221.6; and October 11, 222.2.

The mean discharge rate calculated for the entire thirty week period was 114.4 m^3/sec. Maximum discharge was 497.2 m^3/sec for the week ending May 22, while minimum discharge was 12.7 m^3/sec occurring the week ending September 4.

Average retention time (flushing rate) of reservoir water was based on the average weekly discharge rate (Appendix D) in m^3/sec. The volume discharged for a twenty-four hour period was divided into the volume of the conservation pool and the resulting number was the retention time in days. The calculated retention time varied from 2.58 for the week ending May 22 to a maximum of 109 days for the week ending September 11. The average retention time for the 30 week study based on the average discharge was 11.2 days.

Biological data.

The average number of copepods and cladocerans collected per liter at each transect and station 4 are presented in Table 2. The populations of the transects and station 4 were calculated by adding the number of each species from all depths together and dividing by the total number of liters collected.

Since the stations on each transect had similar populations, physical and chemical properties, they were considered as a single unit. An exception was station four which was located in the large, shallow White-Breast Bay and its population fluctuations varied from those in the main reservoir.

Table 2. The average number of Copepoda and Cladocera collected per liter at each transect and station four.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
4/17	1.7	1.3	1.3	4.7
4/24	3.8	0.6	0.5	3.0
5/1	7.5	1.3	0.7	4.9
5/8	2.1	0.6	1.3	2.2
5/15	4.2	0.4	0.2	1.3
5/22	7.3	1.7	1.2	9.1
5/28	6.2	4.8	1.8	39.1
6/5	16.0	6.8	0.7	36.1
6/12	43.5	18.7	6.5	22.4
6/19	79.9	22.3	44.9	50.5
6/26	33.6	10.7	5.4	17.6
7/2	7.1	17.7	11.9	40.9
7/10	12.4	20.1	9.8	23.2
7/17	19.2	24.9	18.7	19.1

Table 2. Continued.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
7/24	56.7	8.0	5.1	28.5
7/31	19.1	15.5	7.2	27.9
8/7	18.1	17.6	14.1	21.2
8/14	11.4	3.2	2.8	5.5
8/21	21.0	15.2	4.7	11.4
8/28	27.6	19.2	10.5	13.6
9/4	42.6	25.3	14.7	27.2
9/11	33.2	39.1	15.2	31.6
9/18	28.3	10.8	4.8	21.0
9/25	28.9	10.3	4.6	14.1
10/2	19.2	7.4	2.6	16.3
10/9	18.1	9.4	2.9	4.8
10/16	6.1	2.8	0.9	8.2
10/23	7.2	2.4	1.1	5.9
10/30	2.4	1.9	0.7	2.7
11/6	1.3	0.7	0.2	0.8

A gradual increase in zooplankton abundance was noted prior to June 5. The late spring peak in population growth occurred at three transects (79.9/l, 22.3/l, 44.9/l) on June 19. A summer peak occurred on transect two (24.9/l) and transect three (18.7/l) on July 17 and transect one (56.7/l) on July 24. In the late summer a sharp fluctuation in abundance occurred. A decrease occurred from August 7 to August 14, then an increase occurred August 21 on all three transects and station four. An early fall peak in abundance occurred from September 4 on transect one (42.6/l) to September 11 on transect two (39.1/l) and three (15.2/l). A gradual decrease in abundance was noted from September 18 to the end of the sampling period on all three transects.

The late spring peak in population growth that occurred at station four consisted of a series of three pulses: May 28 (39.1/l), June 19 (50.5/l) and July 2 (40.9/l). The summer abundance peak occurred on July 24 (28.5/l). The early fall population growth peak occurred on September 11 (31.6/l). A similar gradual decrease in population abundance was noted from September 18 to November 6.

Twenty-one species were identified (Appendix E). The most abundant forms were Cyclops bicuspidatus thomasi, Diaptomus siciloides, Daphnia pulex, Daphnia ambigua, Bosmina longirostris, Moina micrura, Ceriodaphnia quadrangula, and Diaphanosoma brachyurum.

The main reservoir species responsible for the June 19 population peak were _Cyclops bicuspidatus thomasi_, _Daphnia ambigua_, _Daphnia pulex_, and _Bosmina longirostris_. The most abundant species of the summer peak on July 24 were _Diaptomus siciloides_, _Bosmina longirostris_, and _Moina micrura_. The early fall (September 4 and 11) population peak species were _Diaptomus siciloides_, and _Diaphanosoma brachyurum_. The abundant species responsible for the various populations peaks on station four were the same as those in the main reservoir.

The remaining species occurred in small numbers, except _Cyclops varicans rubellus_ which was quite common during August and September. _Diaptomus clavipes_ occurred only at the beginning of the study. Four species of _Daphnia_ were found. _D. pulex_ was present throughout the study, while _D. ambigua_ disappeared by midsummer. _Daphnia catawba_ and _D. rosea_ appeared in small numbers in the late fall. _Moina micrura_ appeared on June 12, reached a population peak during July, and disappeared early in September. _Ceriodaphnia quadrangula_ did not appear until early September and only remained until October 23. _Diaphanosoma brachyurum_ appeared in the samples on June 12 and was an abundant species until mid-October. _D. leuchtenbergianum_ appeared in mid-October and was abundant until the end of the sampling period.

The total number per total liters of the predominant forms are presented for the transects and station four in the Appendices.

DISCUSSION

Multiple regression analysis.

The water temperatures observed during this study followed the same general pattern recorded by Schmidt (1968), Cowell (1970), and Volker (1962); that is, a gradual increase in temperature until a maximum was reached in July, followed by a gradual decline.

The regression correlations (r) and computed t-values for temperature and the seven most abundant genera (Tables 3-5) indicate that there might be a general, direct relationship between temperature and Cyclops (0.25, 0.47, 0.36) and Moina (0.46). While Diaptomus (0.31, 0.19), Bosmina (0.31, 0.27, 0.25) and Diaphanosoma (0.33, 0.27) showed a slight relationship. There was no correlation between Daphnia and Ceriodaphnia populations and temperature.

Secchi disc readings were lower than those recorded by Cooke (1966) in Lake West Okoboji. The highest values occurred under reasonably stable conditions of low discharge rate and water level. This was in contrast to Coralville Reservoir (Schmidt, 1970) where the maximum readings occurred during periods of high water levels. The effects of precipitation, runoff, and wind-caused wave action on water transparency were similar to those effects observed by Cowell (1970) and Schmidt (1968).

Multiple regression analysis between Secchi disc readings and genera populations (Tables 3-5) showed a

Table 3. The regression correlation and computed t value of the significance of the regression correlation for each genera population and the chemical and physical properties of transect 1. N = 196. (*significant, **highly significant).

Variable Reg. correl. t value	GENERA Cyclops	Diaptomus	Daphnia	Bosmina	Moina	Ceriodaphnia	Diaphanosoma
Depth							
	-0.02	0.09	0.06	0.15	0.07	-0.01	0.08
	0.19	2.21*	1.09	2.48**	1.22	-0.24	2.19*
Temperature							
	0.25	0.31	-0.04	0.31	0.40	-0.09	0.33
	5.28**	3.08**	1.02	-1.53	1.30	-1.22	5.92**
Light penetration							
	0.05	0.06	-0.15	0.26	0.21	-0.10	-0.06
	-3.44**	-3.24**	-4.63**	-3.17**	-3.48**	-0.32	-5.81**
Nitrate							
	0.35	-0.56	-0.18	0.16	0.14	-0.44	-0.43
	4.38**	-1.75	3.30**	6.50**	4.92**	-2.45**	0.06

Table 3. Continued.

Variable Reg. correl. t value	Cyclops	Diaptomus	Daphnia	Bosmina	Moina	Ceriodaphnia	Diaphanosoma
				GENERA			
Phosphate	0.11 2.61**	-0.43 -2.03*	0.08 0.14	-0.36 -5.74**	-0.32 -3.21**	-0.02 1.32	-0.28 0.05
Turbidity	-0.18 0.75	-0.09 1.14	0.09 2.98**	-0.29 -0.61	-0.38 -1.59	0.05 -1.17	-0.09 2.04*
Water level	-0.07 0.39	-0.11 4.04**	-0.10 3.24**	-0.04 3.82**	-0.12 2.33*	-0.02 3.95**	-0.13 3.10**
Water discharge	0.01 -2.75**	-0.45 -5.00**	-0.24 -5.88**	-0.13 -5.12**	-0.17 -3.86**	-0.26 -3.09**	-0.40 -5.36**
Mult. correl. (%)	31	50	23	34	30	27	46

Table 4. The regression correlation and computed t value of the significance of the regression correlation for each genera population and the chemical and physical properties of transect 2. N = 196. (*significant, **highly significant).

Variable Reg. correl. t value	GENERA Cyclops	Diaptomus	Daphnia	Bosmina	Moina	Ceriodaphnia	Diaphanosoma
Depth							
	0.15	0.10	0.16	-0.13	0.17	0.06	0.07
	7.12**	2.96**	2.03*	3.09**	2.16*	-0.62	3.01**
Temperature							
	0.47	0.26	0.11	0.27	0.46	-0.03	0.27
	2.89**	1.53	2.36**	-1.98*	2.97**	0.66	0.99
Light penetration							
	0.33	0.16	0.32	0.16	0.43	-0.04	-0.01
	2.93**	-0.71	3.73**	1.64	3.01**	-1.84	-3.53**
Nitrate							
	0.14	-0.49	-0.15	0.29	-0.08	-0.26	-0.43
	4.18**	-2.44**	0.57	3.20**	0.46	-0.84	-1.76

Table 4. Continued.

Variable Reg. correl. t value	Cyclops	Diaptomus	Daphnia	Bosmina	Moina	Ceriodaphnia	Diaphanosoma
Phosphate	-0.18 4.03**	-0.02 -0.33	0.00 2.69**	-0.09 1.85	-0.48 -2.45**	0.04 -0.14	-0.19 -0.84
Turbidity	-0.34 0.85	-0.09 2.93**	-0.12 1.61	-0.16 -0.45	-0.35 0.46	-0.02 -0.13	-0.08 2.28*
Water level	-0.15 0.36	-0.14 2.95**	-0.12 1.22	0.06 0.45	-0.15 0.44	-0.03 2.67**	-0.13 2.70**
Water discharge	0.24 -2.76**	-0.42 -4.46**	-0.28 -2.50**	0.06 -0.57	-0.27 -1.04	-0.19 -2.66**	-0.35 -4.18**
Multi. correl. (%)	44	40	22	20	37	12	35

GENERA: Cyclops, Diaptomus, Daphnia, Bosmina, Moina, Ceriodaphnia, Diaphanosoma

Table 5. The regression correlation and computed t value of the significance of the regression correlation for each genera population and the chemical and physical properties of transect 3. N = 201. (*significant, **highly significant).

Variable Reg. correl. t value	GENERA Cyclops	Diaptomus	Daphnia	Bosmina	Moina	Ceriodaphnia	Diaphanosoma
Depth							
	0.18	0.10	0.17	-0.05	0.07	0.03	0.01
	3.29**	1.76	2.90**	-0.64	1.17	0.47	0.50
Temperature							
	0.36	0.19	0.22	0.25	0.47	-0.02	0.27
	4.65**	2.89**	3.54**	2.05*	1.54	1.17	4.86**
Light penetration							
	0.26	0.09	0.27	0.05	0.29	-0.01	0.09
	2.19*	1.50	3.26**	-1.21	1.47	0.47	1.66
Nitrate							
	-0.10	-0.41	-0.15	-0.16	-0.33	-0.23	-0.39
	0.68	-2.38**	0.03	-3.73**	-1.48	-1.18	-2.03*

Table 5. Continued.

Variable Reg. correl. t value	Cyclops	Diaptomus	Daphnia	Bosmina	Moina	Ceriodaphnia	Diaphanosoma
				GENERA			
Phosphate							
	-0.24	0.12	-0.05	-0.19	-0.45	0.26	0.11
	-0.69	2.91**	1.23	-2.28*	-4.77**	2.86**	4.01**
Turbidity							
	-0.15	0.08	-0.15	-0.13	0.16	-0.05	0.05
	-4.45**	-0.28	-3.45**	-5.80**	-1.12	-0.82	-0.86
Water level							
	-0.08	-0.10	-0.05	0.08	-0.13	-0.05	-0.11
	1.20	0.72	1.50	1.03	1.51	0.99	-0.03
Water discharge							
	-0.17	-0.32	-0.19	-0.02	-0.27	-0.20	-0.31
	-1.47	-0.06	-1.29	0.92	-2.07*	-0.72	-0.03
Mult. correl. (%)	31	24	23	22	40	13	26

general relationship between light penetration and _Cyclops_ (0.05, 0.33, 0.26), _Moina_ (0.21, 0.43), and _Daphnia_ (-0.15, 0.32, 0.27). The other genera showed little correlation with light penetration.

The turbidity values for Red Rock Reservoir were high and directly related to runoff. The turbidity conditions of Red Rock were similar to those observed in Coralville Reservoir (Schmidt, 1968) and in Lewis and Clark Lake, and Francis Case Lake (Cowell, 1970), South Dakota Reservoirs. A general inverse correlation was found between turbidity and genera populations of _Cyclops_ (-0.15), and _Bosmina_ (-0.13). The other forms showed little correlation with turbidity.

The pH values for the reservoir were usually about 8.0, except during the periods of heavy runoff when 7.5 was common. This coincided with the reported values from the Des Moines River during low and high flow (Drum, 1963; Baumann and Kelman, 1970).

The nitrate nitrogen and phosphate values for Red Rock Reservoir were much higher than those observed in Lake West Okoboji (Cooke, 1966), Lake East Okoboji (Volker, 1962), and the Des Moines River (Drum, 1963; Bauman and Kelman, 1970). The nitrate nitrogen values followed a pattern of high values in early April with a decrease during May. During the major influx of water from the Des Moines River in late May the nitrate values were again high. From late June until mid-November there was a decline in these values. The phosphate values followed a similar pattern except in late August when an increase began and high levels were attained early in November. These patterns in the nitrate and phosphate levels were similar to those observed in John Redmond Reservoir during its early impoundment (Prophet, 1966). Prophet (1966) observed that high nutrient levels in newly formed reservoirs appeared to be typical during the first few years of impoundment. An additional source of nutrients for Red Rock Reservoir might be due to the runoff from fertilized croplands and the sewage effluent from a large urban complex 96.6 km upstream from the dam.

The regression correlations for nitrate and phosphate values and the seven most abundant genera indicate there may be some relationship between population level and nitrate and phosphate level (Tables 3-5). The correlation values between nitrate nitrogen and populations showed an inverse correlation with the following genera: *Diaptomus* (-0.49, -0.41), *Ceriodaphnia* (-0.44), and *Diaphanosoma* (-0.39). Phosphate levels showed an inverse correlation with *Moina* (-0.32, -0.48, -0.45), while *Diaptomus* (-0.43, 0.12) and *Bosmina* (-0.36, -0.19) showed only a slight relationship. The remaining genera showed no definite relationship with nitrate and phosphate levels.

Since the correlation data did not show a definite relationship between all the abundant genera and nutrient levels, the data were re-examined. A time interval occurred between the nutrient (nitrate and phosphate) levels and the population abundance peaks (Figure 2) on transect one and the other two transects had similar patterns. The highest levels of nutrients occurred on June 1 and were followed eighteen days later by the late spring population maximum. The summer population peak was not preceded by a nutrient increase, but the nitrate and phosphate levels were high. The fall population pulse on transect 1 and 2 were again preceded by an increase in nitrate levels (August 24) and phosphate levels (August 11). The population peaks on transect 3 that occurred July 17 and September 11 varied from those on transect 1 and 2 by the number of days elapsing since the nutrient increases. There was a lag of 19 and 32 days between the nutrient level increases and the population peaks.

Populations that showed the greatest inverse relationship to water discharge (Tables 3-5) were *Diaptomus* (-0.45, -0.42) and *Diaphanosoma* (-0.40, -0.35). The genera populations that showed a slight inverse relationship were *Daphnia* (-0.24, -0.28), *Moina* (-0.17, -0.27), and *Ceriodaphnia* (-0.26, -0.19). The other genera did not show a definite correlation with water discharge. Water level showed no correlation with population numbers at any transect.

Conditions in White-Breast Bay, station 4, differed from those in the main reservoir and therefore the data was analyzed separately (Table 6). A chemical station was not

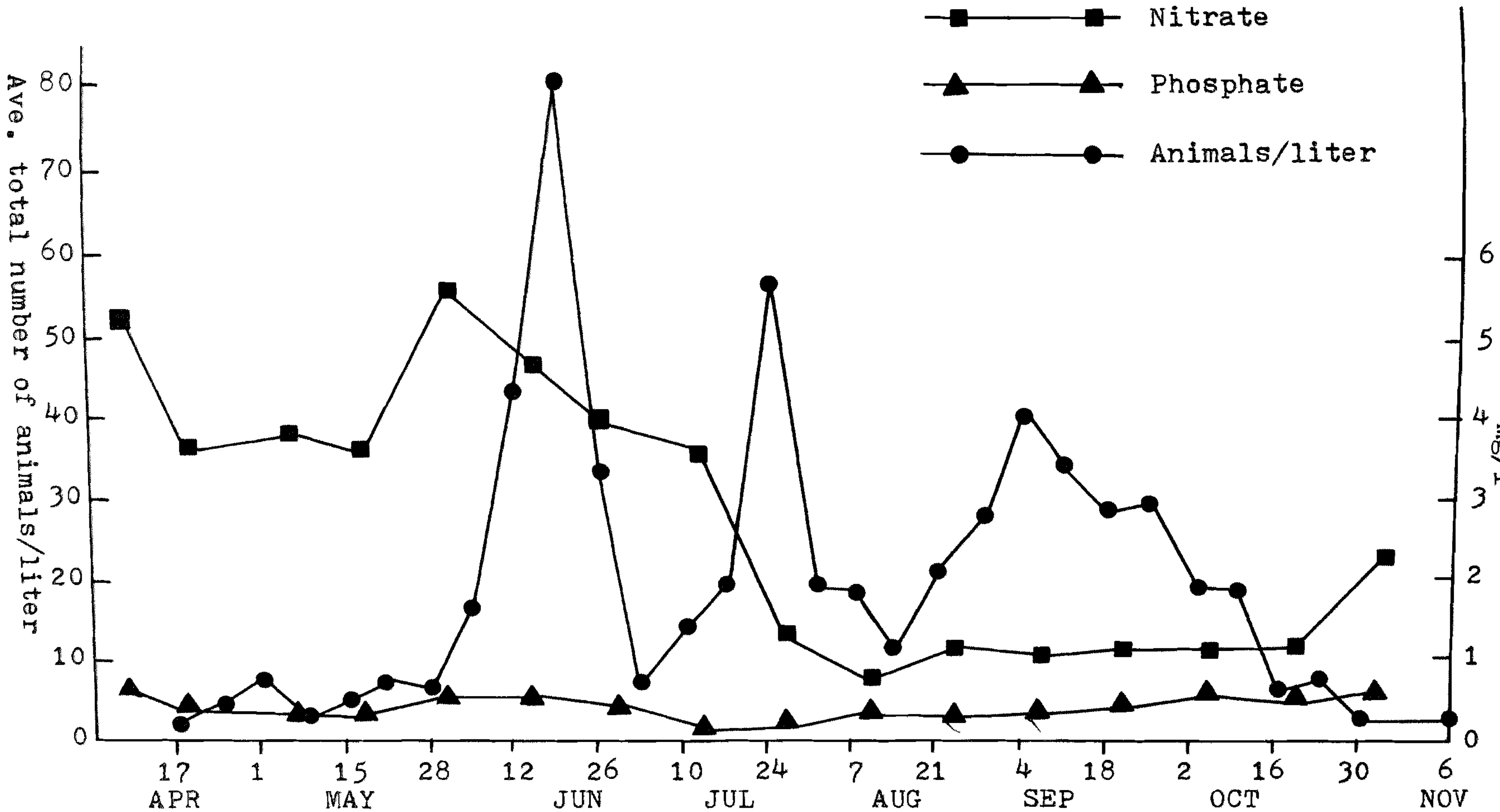

Figure 2. A figure showing the relationship of nitrate, phosphate, and animals per liter for transect 1.

Table 6. The regression correlation and computed t value of the significance of the regression correlation for each genera population and the physical properties of station 4. N = 170. (*significant, **highly significant).

Variable Reg. correl. t value	GENERA Cyclops	Diaptomus	Daphnia	Bosmina	Moina	Ceriodaphnia	Diaphanosoma
Depth							
	0.10	0.00	0.05	0.08	0.13	-0.08	-0.03
	2.38**	0.36	0.89	1.63	2.53**	-1.41	-0.19
Temperature							
	0.33	0.32	-0.03	0.20	0.53	-0.17	0.24
	5.63**	1.56	2.25*	3.79**	2.69**	-1.64	1.66
Light penetration							
	0.19	0.23	-0.03	0.15	0.40	-0.16	0.10
	1.62	0.43	0.52	2.78**	1.64	-2.13*	-1.14

Table 6. Continued.

Variable Reg. correl. t value	GENERA						
	Cyclops	Diaptomus	Daphnia	Bosmina	Moina	Ceriodaphnia	Diaphanosoma
Water level							
	0.04	-0.13	0.15	0.27	-0.18	-0.01	-0.11
	-1.79	3.54**	-0.15	-1.95	1.38	3.33**	3.08**
Water discharge							
	0.14	-0.43	0.17	0.40	-0.27	-0.19	-0.37
	1.35	-3.99**	0.81	3.51**	-3.01**	-2.84**	-4.07**
Mult. correl. (%)	41	45	13	36	44	22	28

located within the confines of the bay thus no correlation could be determined between chemical features and population numbers. Light penetration correlated with the numbers of Moina (0.40). Water discharge showed an inverse correlation with Diaptomus (-0.43), Diaphanosoma (-0.37), and Moina (-0.27) and a direct relationship with Bosmina (0.40). Cyclops (0.33) and Moina (0.53) correlated with temperature.

The square of the multiple correlation expressed as a percentage, indicates the sum total effect of the physical and chemical variables on each genera population. The highest percentages (41, 44, 45) with genera occurred at station 4 (Table 6). Cyclops, Diaptomus, and Moina were affected the greatest, Daphnia was affected the least with the remaining forms only intermittently affected. Diaptomus and Moina showed a strong, direct correlation with temperature and an inverse relationship with water discharge. Physical features are more easily influenced in a shallow area such as White Breast Bay.

Multiple correlation percentages varied with the particular genus at the different transects. Values of 50 and 46 occurred at transect 1 when high regression correlations occurred with water discharge, nitrate, and phosphate values. The higher multiple correlations on transect 2 coincided with high regression correlations with water discharge, temperature, and nitrate values. Multiple correlations at transect three ranged from 13 to 40%. The highest value occurred with a high phosphate and temperature regression correlations.

The multiple correlation percentages increased from transect 3 to transect 1 (down reservoir) for Diaptomus, Bosmina, and Diaphanosoma. A decrease down-reservoir was noted with Moina. Cyclops, Daphnia, and Ceriodaphnia multiple correlation percentages remained relatively constant throughout the reservoir.

Species composition.

The species composition and seasonal abundance of micro-crustaceans in Red Rock Reservoir were similar to those found in reservoirs of Kansas, South Dakota, and the natural lakes of northern Iowa (Prather and Prophet, 1969; Cowell, 1970; Tash et al., 1966). The most abundant genera occurring in the Okoboji region were the same as those found in Red Rock with the exception of Leptodora and Pleuroxus (Stromsten, 1920a, b).

The patterns of seasonal abundance of the copepods and cladocerans in Red Rock varied from those of Clear Lake, Iowa (Bulkley and Scheider, 1970). In Clear Lake, Cyclops did not show a distinct seasonal trend; whereas, the Cyclops of Red Rock showed a distinct spring pulse. In Lewis and Clark Lake and Francis Case Lake (Cowell, 1970; Tash et. al., 1966) Diaptomus clavipes was the most abundant calanoid occurring throughout the year; whereas, D. siciloides was most abundant in October. In Red Rock Reservoir D. clavipes was present only for a short period in April and D. siciloides was present and abundant from May to November.

Diaphanosoma brachyurum appeared to be a common limnetic form in Red Rock Reservoir. However, Brooks (1959) described it as a littoral species. Studies on other reservoirs (Tash et. al., 1966; Prather and Prophet, 1969; Cowell, 1970) have shown that D. brachyurum was common in the open water zone.

A general trend that occurred was the seasonal change in the species composition at all three transects and station four (Table 7). In April, ten species were present. In May, five abundant forms were present, except for Diaptomus clavipes which disappeared from the samples in late April. During June, five species had abundant population peaks. In July, the abundant forms of June were present in high numbers, except for Daphnia ambigua which disappeared from the samples. In August, Cyclops varicans rubellus and Paracyclops fimbriatus poppei appeared. During September, the predominant species were Diaptomus siciloides and Diaphanosoma brachyurum. Moina micrura disappeared from the samples in early September. In October, Daphnia pulex and Diaphanosoma brachyurum were the abundant species. In mid-October Diaphanosoma leuchtenbergianum appeared in small numbers. Cyclops varicans rubellus, Paracyclops fimbriatus poppei, and Ceriodaphnia quadrangula disappeared from the samples in late October. During the first week in November, five species were present.

Table 7. Seasonal fluctuations in abundance in Red Rock Reservoir during 1970. Abundant A, Common C, Rare (few) R.

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
C. b. thomasi	R	C	A	A	R	C	C	R
C. v. rubellus					C	C	R	
P. f. poppei					R	R	R	
D. clavipes	R							
D. siciloides	R	R	R	C	C	A	C	R
A. costata							R	
A. quadranularis							R	
A. rectangula	R	R				R		
B. longirostris	R	R	A	C	R	R	R	R
C. quadrangula						R	R	
D. ambigua	R	R	A	R		R		
D. catawba							R	
D. pulex	R	R	A	A	R	C	A	R
D. rosea							R	
D. brachyurum			R	C	A	A	C	
D. leuchtenbergianum							R	R
L. kindtii				R	R			
L. quadrangularis	R							
M. laticornis	R		R					
M. micrura			C	A	A	R		
P. denticulatus	R							

A general trend noted was that population numbers of a species began to increase first at transect 1 then succeeding increases were shown at transects 2 and 3. The population numbers of a given species began decreasing first in the upper end of the reservoir (transect 3). The population persisted for the longest period of time at the dam area (transect 1). Populations in White Breast Bay (station 4) peaked at different times than the other stations within the reservoir.

Controlling factors of microcrustacean populations can be only completely understood when a reservoir can be studied as a complete system. To obtain more conclusive results more trophic levels should be included. Algae are a very important link between nutrients and primary consumers. More inclusive monitoring of the water chemistry and collection of water samples concurrent with the biota samples. Nutrient inflow and outflow and amounts present within the reservoir should be more accurately determined. Interspecific relationships such as predation, competition, and grazing need to be determined and their effects on species composition and abundance determined.

SUMMARY

1. From April 17 to November 6, 1970, volumetric samples of zooplankton were taken at ten stations located on three transects within Red Rock Reservoir. The species composition and abundance were determined.
2. The physical and chemical characteristics of Red Rock Reservoir were similar to those found in reservoirs in Kansas, South Dakota, and Iowa.
3. Temperature and water discharge showed the strongest correlation with genera abundance. Phosphate, nitrate and turbidity showed some correlation.
4. A time interval of 18 to 32 days occurred between nutrient increases and the late spring and early fall population pulses.
5. Species composition was similar to reservoirs in Kansas, South Dakota and the natural lakes of Iowa.
6. Species composition showed distinct seasonal changes.
7. Species population numbers began to increase in the dam area (transect 1) with succeeding increases in the upper reservoir. Maximum populations were obtained at transect 1 and populations existed here for the longest period of time.

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APPENDICES

Appendix A. Water temperatures (°C) at the surface and bottom for each station. A single value indicates both temperatures were the same.

	STATIONS									
Date	1	2	3	4	5	6	7	8	9	10
4/17	11.0 12.0	11.0	11.0 12.0	12.0	12.5 12.0	12.0 11.5	12.0	12.0	12.5	12.0 12.5
4/24	12.0 11.0	14.0 11.0	13.0 11.0	13.0 11.0	15.0 14.0	15.0 13.0	14.0	14.0 13.0	14.0	15.0 14.0
5/1	16.0 17.0	17.0	17.0	16.0	17.0 18.0	17.0 18.0	16.0 17.0	17.0	16.0	17.0
5/8	17.0	17.0	17.0	18.0 17.0	18.0	18.0	18.0	19.0 18.0	20.0	20.0
5/15	18.0 19.0	19.0	19.0	18.0	16.0 17.0	16.0 17.0	16.0 17.0	16.0 17.0	16.0	16.0
5/22	20.0 18.0	20.0	20.0 18.0	21.0 20.0	21.0 20.0	21.0 19.0	21.0	22.0 18.0	22.0 21.0	22.0 21.0
5/28	22.0 21.0	21.0	21.0	21.0	21.0 22.0	21.0 22.0	21.0	21.0 20.0	21.0	22.0
6/5	20.0	20.0	20.0	21.0 19.0	20.0	20.0 19.0	20.0	21.0 20.0	21.0 20.0	21.0 20.0

Appendix A. Continued.

	STATIONS									
Date	1	2	3	4	5	6	7	8	9	10
6/12	23.0 22.0	23.0	23.0	23.0	23.0	23.0	23.0	24.0	23.0	23.0
6/19	25.0 23.0	24.5 24.0	24.5 24.0	25.0 23.0	25.0 24.5	25.0 24.0	25.0 24.5	27.0 24.0	25.0 24.5	25.0 24.5
6/26	23.0	23.0	23.5	23.0	23.0	23.0	23.0	23.5 23.0	23.5	23.0
7/2	27.5 23.0	27.5 24.0	27.5 24.5	27.5 25.0	27.5 27.0	28.0 24.0	28.5	29.0 24.0	29.0 28.0	29.0 28.5
7/10	27.0 23.0	26.5 24.0	26.5 24.0	27.0 23.0	26.0 24.0	27.0 23.0	25.0 23.0	27.5 22.0	28.0 25.5	27.0 25.5
7/17	26.0 25.0	26.0 25.0	26.0 25.5	25.0	25.0	26.0 25.0	25.0	27.0 25.0	25.5	26.0 25.5
7/24	24.0 23.5	23.0	23.0	23.0 22.5	23.0	24.0 23.0	24.0	24.0 23.0	24.0	24.0
7/31	28.5 24.0	28.0 26.0	28.0 25.5	28.5 24.5	28.5 28.0	28.5 24.0	28.5	28.5 26.0	28.5	28.0

Appendix A. Continued.

	STATIONS									
Date	1	2	3	4	5	6	7	8	9	10
8/7	24.0	24.0	24.0	23.5 23.0	23.0	23.0	23.0	23.0	23.0	23.0
8/14	24.0 22.0	24.0 22.5	24.5 22.5	25.0 23.0	25.5 25.0	25.0 23.5	25.0	26.0 24.0	25.5	26.0
8/21	24.0	25.0	24.0	24.0	24.0	24.0 23.5	23.0	24.0	25.0	24.0 24.5
8/28	24.0 23.0	24.0 23.0	24.5 23.0	25.0 23.0	25.0 24.5	25.0 23.0	26.0 25.0	25.5 23.0	25.5 25.0	25.5 25.0
9/4	24.0 24.5	24.0 24.5	24.0 24.5	24.5	24.5 24.0	24.0	24.0	25.0 24.5	24.5	24.5
9/11	21.5	21.5	21.5	20.5 20.0	20.5	21.0 20.5	20.0	20.5	20.5	20.0
9/18	17.5	17.5	17.5	15.5 15.0	16.0	16.0 15.5	16.0	16.0 15.5	16.0	16.0
9/25	17.5	17.5 18.0	17.5	17.0 16.0	17.5	17.5	17.5	17.5	18.0	18.0

Appendix A. Continued.

Date	STATIONS									
	1	2	3	4	5	6	7	8	9	10
10/2	16.5 16.0	16.5	17.0 16.5	16.5 16.0	16.5 16.0	16.5 16.0	17.5	17.0 16.5	17.0	17.0
10/9	15.5	15.5	15.5	11.5	15.0	15.0 15.5	14.5	14.5 15.0	15.0	14.5 15.0
10/16	11.0	11.5 11.0	11.5	10.5 9.5	11.0 10.5	11.0 10.5	11.0 10.5	11.5 11.0	11.0 11.5	11.0
10/23	11.5	11.5	11.5	12.5 12.0	13.5	13.0 12.5	12.5	13.0 12.5	12.5	12.5
10/30	11.5	11.5	11.5 11.0	10.5 10.0	10.5	10.5	9.5	10.0	9.0	9.5
11/6	7.5	7.5	7.5	7.5	7.0	7.0	7.5	7.5 6.5	7.0	8.0

Appendix B. Light penetration (cm).

	STATIONS									
Date	1	2	3	4	5	6	7	8	9	10
4/17	30	30	30	10	30	30	30	30	30	30
4/24	30	30	30	30	30	30	30	30	30	30
5/1	30	30	30	20	30	30	30	30	30	30
5/8	60	60	40	30	30	30	30	40	30	30
5/15	50	50	50	10	7.5	7.5	10	7.5	7.5	7.5
5/22	40	30	20	30	30	30	30	30	30	30
5/28	40	40	40	20	20	20	30	30	20	10
6/5	30	30	30	30	30	30	30	30	30	30
6/12	60	50	50	20	20	20	20	30	20	20
6/19	50	50	50	40	40	30	30	20	20	20

Appendix B. Continued.

	STATIONS									
Date	1	2	3	4	5	6	7	8	9	10
6/26	50	50	50	20	20	20	20	20	20	20
7/2	90	90	100	30	50	50	40	40	30	30
7/10	90	90	90	70	70	70	60	60	50	50
7/17	80	80	80	40	40	40	40	40	30	30
7/24	60	40	40	40	40	40	40	40	30	40
7/31	90	80	80	50	70	70	50	50	40	40
8/7	80	80	70	30	40	40	40	30	40	40
8/14	15	20	20	10	20	20	20	20	20	20
8/21	20	20	20	20	20	20	20	30	20	20
8/28	25	30	30	30	40	40	40	30	30	30

Appendix B. Continued.

	STATIONS									
Date	1	2	3	4	5	6	7	8	9	10
9/4	40	40	40	30	30	30	30	30	30	30
9/11	40	40	40	30	30	30	30	30	30	20
9/18	50	50	50	20	30	50	40	10	10	10
9/25	40	40	40	20	30	30	30	30	20	20
10/2	30	30	30	20	20	20	20	20	20	20
10/9	30	30	30	5	20	20	20	20	20	20
10/16	20	20	20	10	20	20	20	30	30	30
10/23	40	40	40	30	30	30	30	10	5	5
10/30	30	30	30	30	30	30	20	30	30	30
11/6	40	40	40	30	30	30	50	40	40	40

Appendix C. The pH, turbidity, phosphate, and nitrate values obtained from the Iowa Conservation Commission. Turbidity (turb), nitrogen nitrate (NO_3), and orthophosphate (PO_4) values in mg/l. "A" represents a surface sample (56 cm) and "B" represents a sample taken at 4.3 meters.

Date pH turb NO_3 PO_4	IOWA CONSERVATION COMMISSION STATIONS					
	2A	2B	3A	3B	4A	4B
4/7	8.0 63.0 5.2 0.6	8.0 57.0 5.2 0.6	8.0 77.0 5.2 0.4	8.0 82.0 5.2 0.5	8.1 82.0 5.6 0.6	8.1 74.0 5.6 0.6
4/21	7.8 152.0 3.6 0.4	8.0 138.0 3.6 0.4	7.8 364.0 2.6 0.2	7.8 380.0 2.6 0.2	8.0 148.0 3.8 0.5	8.0 180.0 4.0 0.4
5/6	8.2 30.0 3.8 0.3	8.2 32.0 3.8 0.3	8.2 55.0 3.4 0.1	8.2 58.0 3.4 0.2	8.2 110.0 3.3 0.2	8.2 110.0 3.3 0.3
5/19	7.4 330.0 3.6 0.3	7.5 360.0 3.6 0.3	7.5 455.0 3.6 0.3	7.6 490.0 3.4 0.1	7.6 370.0 4.8 0.3	7.6 390.0 5.2 0.2
6/1	7.6 87.0 5.6 0.5	7.8 78.0 5.6 0.5	7.7 100.0 5.6 0.5	7.6 100.0 5.6 0.5	7.8 160.0 5.6 0.5	7.7 200.0 5.6 0.5

Appendix C. Continued.

Date pH turb NO_3 PO_4	IOWA CONSERVATION COMMISSION STATIONS					
	2A	2B	3A	3B	4A	4B
6/15						
	8.0	8.0	8.2	8.2	7.8	7.7
	31.0	44.0	30.0	35.0	128.0	220.0
	5.0	4.4	4.4	4.4	4.4	4.0
	0.5	0.5	0.4	0.5	0.5	0.6
6/29						
	8.0	8.0	8.2	8.2	8.1	8.0
	52.0	82.0	67.0	82.0	120.0	240.0
	4.0	4.0	4.4	4.4	4.8	5.0
	0.4	0.4	0.3	0.5	0.5	0.5
7/13						
	8.2	8.2	7.9	8.0	8.2	8.0
	28.0	32.0	59.0	49.0	63.0	70.0
	3.6	3.6	3.0	2.8	0.3	0.3
	0.1	0.1	0.1	0.1	0.2	0.2
7/28						
	8.1	7.6	8.2	7.8	8.2	7.8
	17.0	30.0	27.0	44.0	42.0	78.0
	1.3	1.5	1.2	0.8	0.2	0.2
	0.1	0.2	0.1	0.2	0.3	0.6
8/11						
	7.6	7.6	7.5	7.4	7.4	7.1
	96.0	100.0	520.0	1,000.0	880.0	940.0
	0.8	0.7	0.6	0.8	0.8	0.9
	0.4	0.3	0.2	0.2	0.2	0.1
8/24						
	7.2	7.1	7.3	7.3	8.0	7.5
	180.0	200.0	220.0	200.0	77.0	330.0
	1.2	1.2	1.2	1.2	0.9	0.9
	0.3	0.3	0.3	0.3	0.6	0.8

Appendix C. Continued.

Date / Variable	IOWA CONSERVATION COMMISSION STATIONS					
	2A	2B	3A	3B	4A	4B
9/8						
pH	7.5	7.5	7.5	7.6	7.6	7.6
turb	95.0	95.0	97.0	120.0	170.0	150.0
NO_3	1.0	1.0	1.0	1.0	0.9	0.8
PO_4	0.3	0.4	0.3	0.3	0.6	0.7
9/22						
pH	8.0	8.0	8.0	7.9	7.8	7.8
turb	66.0	59.0	78.0	82.0	160.0	190.0
NO_3	1.0	1.1	1.0	1.0	0.7	0.8
PO_4	0.4	0.4	0.4	0.4	0.9	0.8
10/6						
pH	7.6	7.6	7.5	7.6	7.6	7.6
turb	140.0	140.0	190.0	180.0	230.0	240.0
NO_3	1.1	1.1	1.1	1.1	1.2	1.2
PO_4	0.5	0.6	0.7	0.7	0.9	0.9
10/20						
pH	7.3	7.2	7.4	7.7	8.2	8.2
turb	200.0	230.0	160.0	160.0	140.0	170.0
NO_3	1.1	1.2	1.5	1.8	2.9	2.8
PO_4	0.5	0.4	0.6	0.7	0.9	0.9
11/3						
pH	7.4	7.5	7.7	7.8	7.9	7.9
turb	100.0	110.0	120.0	110.0	94.0	89.0
NO_3	2.2	2.2	2.6	2.6	2.8	3.1
PO_4	0.6	0.6	0.8	0.7	0.7	0.7
11/17						
pH	7.6	7.7	7.7	7.8	7.8	7.8
turb	95.0	95.0	130.0	120.0	70.0	64.0
NO_3	2.3	2.3	2.8	2.9	4.0	4.0
PO_4	0.5	0.6	0.5	0.6	0.8	0.8

Appendix D. The average weekly discharge rate, the conservation pool level and the average retention time of the water contained within the conservation pool. Discharge rate is in m3/sec. Water level is in meters above mean sea level. The retention time is in days. (This information was obtained from the U.S. Army Corps of Engineer's Office at Red Rock Reservoir, Iowa.)

Week ending	Water level	Average discharge	Retention time
4/17	221.6	213.6	6.02
4/24	221.3	227.3	5.65
5/1	221.1	211.2	6.08
5/8	221.1	128.9	10.0
5/15	221.3	161.6	7.95
5/22	223.6	497.2	2.58
5/28	222.6	491.8	2.61
6/5	221.2	175.0	7.34
6/12	221.1	117.2	11.0
6/19	221.3	121.2	10.6
6/26	221.1	116.0	11.1
7/2	221.2	71.0	18.1
7/10	221.2	48.8	26.3
7/17	221.2	37.4	34.4

Appendix D. Continued.

Week ending	Water level	Average discharge	Retention time
7/24	221.2	28.5	45.1
7/31	221.2	28.6	44.9
8/7	221.2	36.0	35.7
8/14	221.4	179.7	7.15
8/21	221.2	37.9	33.9
8/28	221.2	25.3	50.8
9/4	221.2	12.7	102.0
9/11	221.2	11.8	109.0
9/18	221.4	43.0	29.9
9/25	221.4	74.2	17.3
10/2	221.3	62.9	20.4
10/9	221.2	17.7	72.6
10/16	221.6	159.2	8.07
10/23	221.1	78.2	16.4
10/30	221.0	112.0	11.5
11/6	221.1	64.4	20.0

Appendix E. List of Species of Copepoda and Cladocera.

Copepoda: Cyclopodia

Cyclops bicuspidatus thomasi S. A. Forbes 1882.

Cyclops varicans rubellus Lilljeborg 1901.

Paracyclops fimbriatus poppei (Rehberg) 1880.

Copepoda: Calanoida

Diaptomus clavipes Schacht 1897.

Diaptomus siciloides Lilljeborg 1889.

Cladocera

Alona costata Sars 1862.

Alona quadranularis (O. F. Müller) 1785.

Alona rectangula Sars 1861.

Bosmina longirostris (O. F. Müller) 1785.

Ceriodaphnia quadrangula (O. F. Müller) 1785.

Daphnia ambigua Scourfeld 1947.

Daphnia catawba Coker 1926.

Daphnia pulex Leydig 1860 emend. Richard 1896.

Daphnia rosea Sars 1862 emend. Richard 1896.

Diaphanosoma brachyurum (Lieven) 1848.

Diaphanosoma leuchtenbergianum Fischer 1850.

Leptodora kindtii (Focke) 1844.

Leydigia quadrangularis (Leydig) 1860.

Macrothrix laticornis (Jurine) 1820.

Moina micrura Kurz 1874.

Pleuroxus denticulatus Birg 1878.

Appendix F. The total number of *Cyclops* spp./total liters collected.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
4/17	87/60	36/39	48/42	72/22
4/24	410/120	48/84	35/78	62/36
5/1	431/60	36/33	24/36	94/21
5/8	171/114	38/72	24/72	50/36
5/15	344/114	19/72	1/72	22/36
5/22	522/114	78/90	68/78	129/36
5/28	150/36	74/24	28/22	172/12
6/5	1316/114	209/69	38/66	534/36
6/12	3704/114	296/72	224/66	392/36
6/19	6967/114	1037/72	242/66	1163/36
6/26	2328/108	603/72	192/60	334/36
7/2	212/108	752/72	593/66	722/36
7/10	376/114	652/72	403/66	232/36
7/17	806/114	613/72	467/66	267/36

Appendix F. Continued.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
7/24	971/114	122/72	72/66	131/36
7/31	262/114	246/72	89/66	144/36
8/7	382/108	253/72	175/66	131/36
8/14	377/114	78/72	53/66	75/36
8/21	262/108	144/72	37/66	74/36
8/28	547/108	207/72	152/66	82/36
9/4	452/108	238/72	129/66	116/36
9/11	338/114	439/72	203/66	152/36
9/18	391/114	137/72	70/66	76/36
9/25	534/114	204/72	88/66	137/36
10/2	375/108	224/72	73/66	170/36
10/9	805/114	341/72	89/66	43/36
10/16	384/114	124/72	40/66	167/36
10/23	483/114	112/72	44/66	118/36
10/30	168/114	70/72	35/66	59/36
11/6	85/114	26/72	7/66	10/36

Appendix G. The total number of <u>Diaptomus</u> spp./total liters collected.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
4/17	3/60	0/39	1/42	0/22
4/24	8/120	2/84	0/78	4/36
5/1	8/60	0/33	1/36	3/21
5/8	3/114	0/72	0/72	1/36
5/15	3/114	0/72	0/72	14/36
5/22	95/114	3/90	0/78	16/36
5/28	1/36	1/24	1/22	5/12
6/5	20/114	5/69	0/66	34/36
6/12	62/114	5/72	1/66	21/36
6/19	54/114	17/72	1/66	33/36
6/26	215/108	17/72	1/60	63/36
7/2	68/108	53/72	19/66	105/36
7/10	177/114	189/72	15/66	116/36
7/17	520/114	272/72	68/66	143/36

Appendix G. Continued

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
7/24	1950/114	195/72	41/66	442/36
7/31	1473/114	336/72	43/66	549/36
8/7	1016/108	380/72	241/66	266/36
8/14	607/114	57/72	41/66	85/36
8/21	867/108	237/72	90/66	115/36
8/28	1445/108	661/72	231/66	296/36
9/4	3089/108	904/72	367/66	641/36
9/11	2154/114	1531/72	514/66	624/36
9/18	1972/114	437/72	190/66	462/36
9/25	1913/114	341/72	144/66	232/36
10/2	958/108	178/72	47/66	222/36
10/9	480/114	163/72	45/66	39/36
10/16	384/114	18/72	6/66	25/36
10/23	91/114	34/72	12/66	28/36
10/30	46/114	28/72	7/66	16/36
11/6	33/114	14/72	3/66	9/36

Appendix H. The total number of <u>Daphnia</u> spp./total liters collected.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
4/17	12/60	5/39	3/42	13/22
4/24	22/120	2/84	4/78	20/36
5/1	21/60	5/33	0/36	3/21
5/8	55/114	5/72	0/72	23/36
5/15	113/114	7/72	0/72	9/36
5/22	71/114	9/10	4/78	39/36
5/28	24/36	7/24	5/22	54/12
6/5	235/114	51/69	6/66	168/36
6/12	571/114	44/72	20/66	107/36
6/19	205/114	66/72	5/66	76/36
6/26	141/108	6/72	2/60	30/36
7/2	8/108	16/72	40/66	36/36
7/10	30/114	159/72	84/66	43/36
7/17	33/114	105/72	31/66	37/36

Appendix H. Continued.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
7/24	376/114	8/72	9/66	37/36
7/31	40/114	52/72	5/66	46/36
8/7	11/108	15/72	1/66	5/36
8/14	19/114	2/72	1/66	1/36
8/21	4/108	9/72	12/66	3/36
8/28	13/108	31/72	12/66	10/36
9/4	237/108	62/72	30/66	23/36
9/11	391/114	96/72	33/66	78/36
9/18	395/114	26/72	16/66	58/36
9/25	375/114	81/72	38/66	67/36
10/2	546/108	96/72	18/66	143/36
10/9	610/114	108/72	32/66	76/36
10/16	200/114	38/72	10/66	80/36
10/23	222/114	18/72	11/66	55/36
10/30	40/114	31/66	6/66	17/36
11/6	21/114	10/72	2/66	9/36

Appendix I. The total number of *Bosmina longirostris*/total liters collected.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
4/17	2/60	9/39	2/42	17/22
4/24	13/120	1/84	0/78	22/36
5/1	2/60	1/33	0/36	3/21
5/8	9/114	0/72	0/72	7/36
5/15	23/114	2/72	0/72	3/36
5/22	108/114	64/90	16/78	142/36
5/28	45/36	32/24	5/22	238/12
6/5	257/114	207/69	0/66	567/36
6/12	257/114	79/72	13/66	162/36
6/19	777/114	271/72	1/66	408/36
6/26	425/108	26/72	2/60	70/36
7/2	61/108	33/72	12/66	109/36
7/10	491/114	181/72	3/66	196/36
7/17	501/114	173/72	77/66	79/36

Appendix I. Continued.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
7/24	1645/114	11/72	7/66	170/36
7/31	173/114	10/72	6/66	39/36
8/7	39/108	3/72	10/66	35/36
8/14	7/114	2/72	6/66	9/36
8/21	8/108	6/72	3/66	2/36
8/28	13/108	2/72	1/66	1/36
9/4	38/108	9/72	7/66	7/36
9/11	40/114	27/72	2/66	12/36
9/18	42/114	1/72	2/66	9/36
9/25	62/114	9/72	3/66	10/36
10/2	63/108	10/72	3/66	18/36
10/9	36/114	13/72	5/66	3/36
10/16	15/114	14/72	3/66	13/36
10/23	14/114	7/72	3/66	10/36
10/30	7/114	6/72	0/66	5/36
11/6	5/114	0/72	2/66	0/36

Appendix J. The total number of *Moina micrura*/total liters collected.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
6/12	354/114	249/72	173/66	123/36
6/19	1093/114	209/72	159/66	133/36
6/26	169/108	109/72	120/60	116/36
7/2	218/108	376/72	121/66	441/36
7/10	90/114	243/72	139/66	179/36
7/17	113/114	588/72	572/66	147/36
7/24	1259/114	196/72	192/66	220/36
7/31	173/114	428/72	320/66	212/36
8/7	414/108	561/72	434/66	296/36
8/14	246/114	72/72	79/66	20/36
8/21	212/108	197/72	45/66	101/36
8/28	58/108	110/72	54/66	24/36
9/4	27/108	40/72	20/66	28/36

Appendix K. The total number of *Ceriodaphnia quadrangula*/total liters collected.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
9/11	86/114	49/72	44/66	15/36
9/18	64/114	9/72	8/66	11/36
9/25	73/114	14/72	4/66	10/36
10/2	30/108	0/72	6/66	12/36
10/9	27/114	5/72	5/66	5/36
10/16	6/114	3/72	0/66	4/36
10/23	7/114	0/72	0/66	0/36
10/30	1/114	1/72	1/66	0/36
11/6	0/114	0/72	0/66	0/36

Appendix L. The total number of <u>Diaphanosoma</u> spp./total liters collected.

Date	Trans. 1	Trans. 2	Trans. 3	Sta. 4
6/12	10/114	0/72	1/66	0/36
6/19	18/114	4/72	0/66	0/36
6/26	35/108	13/72	5/60	19/36
7/2	204/108	45/72	2/66	60/36
7/10	249/114	25/72	3/66	71/36
7/17	27/114	46/72	17/66	16/36
7/24	275/114	44/72	15/66	23/36
7/31	89/114	41/72	10/66	13/36
8/7	92/108	57/72	67/66	29/36
8/14	43/114	12/72	7/66	7/36
8/21	910/108	501/72	125/66	116/36
8/28	899/108	365/72	244/66	76/36
9/4	759/108	567/72	416/66	163/36
9/11	770/114	670/72	205/66	255/36
9/18	366/114	165/72	30/66	140/36
9/25	341/114	93/72	30/66	10/36
10/2	107/108	23/72	24/66	24/36
10/9	105/114	42/72	13/66	8/36
10/16	10/114	3/72	0/66	4/36
10/23	0/114	1/72	0/66	0/36
10/30	1/114	0/72	0/66	1/36
11/6	1/114	1/72	0/66	0/36